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A Novel Method of Testing the Shear Strength of Thick Honeycomb Composites

A. J. Hodge
and A. T. Nettles

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**A Novel Method of Testing
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Thick Honeycomb Composites**

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National Aeronautics and
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TABLE OF CONTENTS

| | Page |
|--|------|
| I. INTRODUCTION | 1 |
| II. SPECIMEN DESCRIPTION..... | 1 |
| 1. Materials | 1 |
| 2. Specimen Fabrication | 3 |
| III. TEST METHODS | 4 |
| 1. Impact Testing..... | 4 |
| 2. Four-Point Bend Testing | 4 |
| 3. Double Lap Shear Testing | 5 |
| IV. TEST RESULTS..... | 7 |
| 1. Impact Testing..... | 7 |
| 2. Four-Point Bend Test..... | 7 |
| 3. Double Lap Shear Test | 7 |
| V. CONCLUSION | 8 |
| APPENDIX—Photographs of Testing Techniques | 9 |
| REFERENCES..... | 10 |

LIST OF ILLUSTRATIONS

| Figure | Title | Page |
|--------|--|------|
| 1. | Lap shear test..... | 2 |
| 2. | Fabrication of lap shear specimen..... | 3 |
| 3. | Dimensions of four-point bend tests..... | 4 |
| 4. | Method of bonding specimens for DLS tests..... | 5 |
| 5. | DLS test fixture..... | 6 |
| 6. | Shear stress versus impact energy..... | 7 |

TECHNICAL PAPER

A NOVEL METHOD OF TESTING THE SHEAR STRENGTH OF THICK HONEYCOMB COMPOSITES

I. INTRODUCTION

Determination of the shear strength of a honeycomb core and carbon-fiber facing composite is normally performed utilizing the American Society for Testing Materials (ASTM) standard ASTM C273, "Shear Test in Flat Sandwich Constructions or Sandwich Cores." ASTM C393, "Flexure Test of Flat Sandwich Constructions," can also be used to determine the shear strength [1], but ASTM C273 is recommended. The ASTM standard calls for a specimen length not less than 12 times the specimen's thickness and a width not less than twice the specimen's thickness. Thus, for thick honeycomb cores, specimens may be too large to fabricate and fit into laboratory scale testing machines. The honeycomb core evaluated in this study, which was being tested for the Advanced Launch System (ALS) program, was 3.6-cm (1.4-in) thick and required a specimen length of at least 42.7 cm (16.8 in). Materials available limited the specimen length to 30.5 cm (12 in).

Previous studies [1,2] have shown that at low-impact energies with no visible surface damage there can still be damage to the core. Cross sections of these low-impact energy specimens show no damage in the form of dents or delaminations on the face sheets. However, a slight ductile buckle occurs in both types of core under the point of impact. Therefore, it is possible that an impact which causes no visible damage to the composite may damage the core sufficiently to reduce the composite's shear stress.

The residual shear strength of impacted honeycomb composites with carbon fiber facesheets and aluminum and glass-phenolic cores was to be determined by two methods: four-point bend and lap shear tests. Since ASTM C273 could not be used to specifications, lap shear testing was attempted with smaller lengths. When this was performed, the facesheets of the composite tended to peel away from the core (fig. 1). An alternate method of lap shear testing was needed. Thus, the "double lap shear" (DLS) test was devised.

II. SPECIMEN DESCRIPTION

1. Materials

Only one carbon fiber prepreg system, T300/934, was used in the tests. The T300 was manufactured by Amoco and preimpregnated with Fiberite 934 resin. Two types of honeycomb cores manufactured by Hexel were compared: glass/phenolic and aluminum. Both cores have a density of 314.3 N/m^3 (2 lb/ft^3), a cell size of 4.76 mm (3/16 in), and a thickness of 35 mm [2]. The crush strengths were previously determined to be 1,158 kPa for the aluminum and 896 kPa for the glass/phenolic [1]. The epoxy film adhesive used to bond the honeycomb cores and the facesheets was EA9684 produced by Hysol.

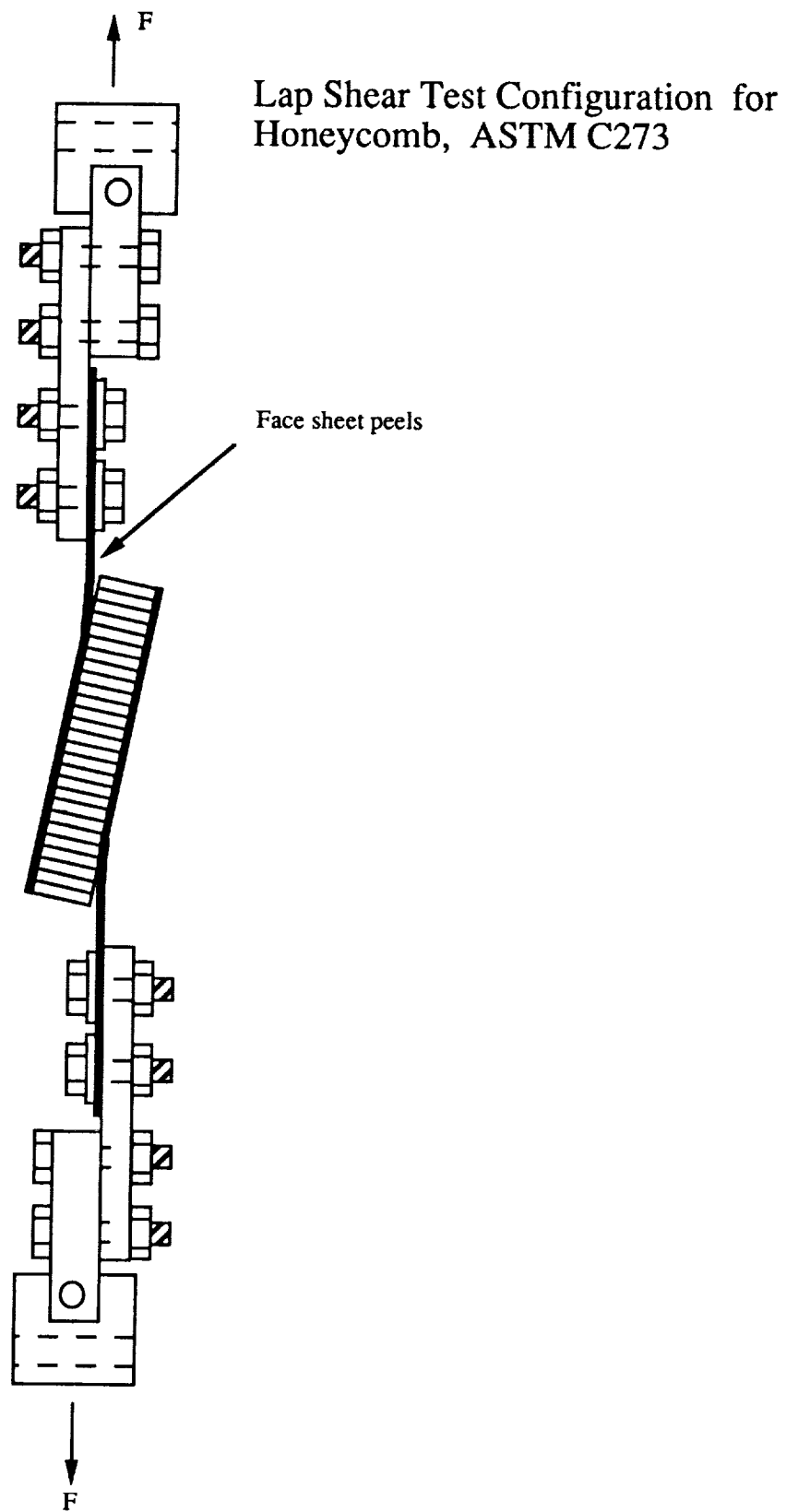


Figure 1. Lap shear test.

2. Specimen Fabrication

The T300/934 prepreg was made into eight-ply lay-ups with $(0,45,-45,90)_s$ quasi-isotropic configurations. A layer of epoxy adhesive film was placed between the facings and honeycomb in order to bond the face sheets to the core [4]. The composite was vacuum bagged and pressurized at 80 kPa from a programmable platen press. The composite was heated at $1.7\text{ }^{\circ}\text{C}$ ($3\text{ }^{\circ}\text{F}$) per minute, cured for 2 hours at $180\text{ }^{\circ}\text{C}$ ($355\text{ }^{\circ}\text{F}$), and then cooled to room temperature at $2.8\text{ }^{\circ}\text{C}$ ($5\text{ }^{\circ}\text{F}$) per minute.

When fully cured, the specimens to be four-point bend tested were cut into beams 29.2 cm (11.5 in) in length and 7.6 cm (3.0 in) in width. The beam's length was in the "L" direction of the honeycomb. These beams were to be four-point bend tested following ASTM C393 guidelines. For the DLS specimens, release film was placed between the honeycomb core and the faceplate as shown in figure 2. The specimens—made with one eight-ply facing and one $(0,90)_s$ four-ply facing—were cut into beams of the same dimensions. Two incisions were then made on opposite facings each 6.35 cm (2.5 in) from the center, making the incisions 12.7 cm (5.0 in) apart. The outer honeycomb was removed as can be seen in figure 2.

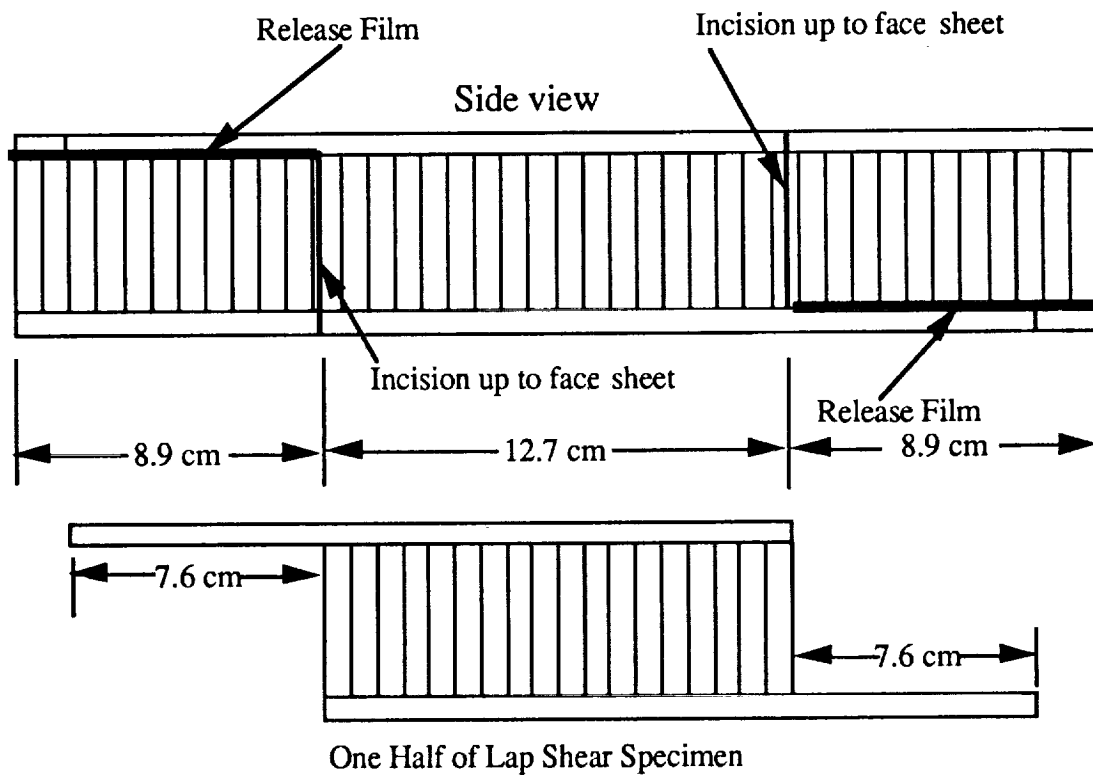


Figure 2. Fabrication of lap shear specimen.

III. TEST METHODS

1. Impact Testing

Samples were impacted at various energy levels ranging from 0 to 8.6 J. Impacting was done with a Dynatup 8200 drop weight impactor, and data were obtained using the Dynatup 730 data acquisition system. The impacting tup's mass was 1.21 kg with a diameter of 1.27 cm (0.50 in). The specimens were pneumatically clamped in place by two aluminum plates with holes of 7.62 cm (3.0 in) in diameter.

2. Four-Point Bend Testing

The specimens were tested for residual shear stress utilizing ASTM standard C393, "Flexure Test of Flat Sandwich Constructions." The inner force contact points were 3.8 cm (1.5 in) from the center, and the outer contact points were 12.7 cm (5.0 in) from the center. The impact points are located 6.35 cm (2.5 in) from the center—halfway between the center and outer force contact points. Aluminum tabs, 3.8 cm (1.5 in), were placed on the area of contact to help distribute the force so that localized core crushing would not occur (fig. 3).

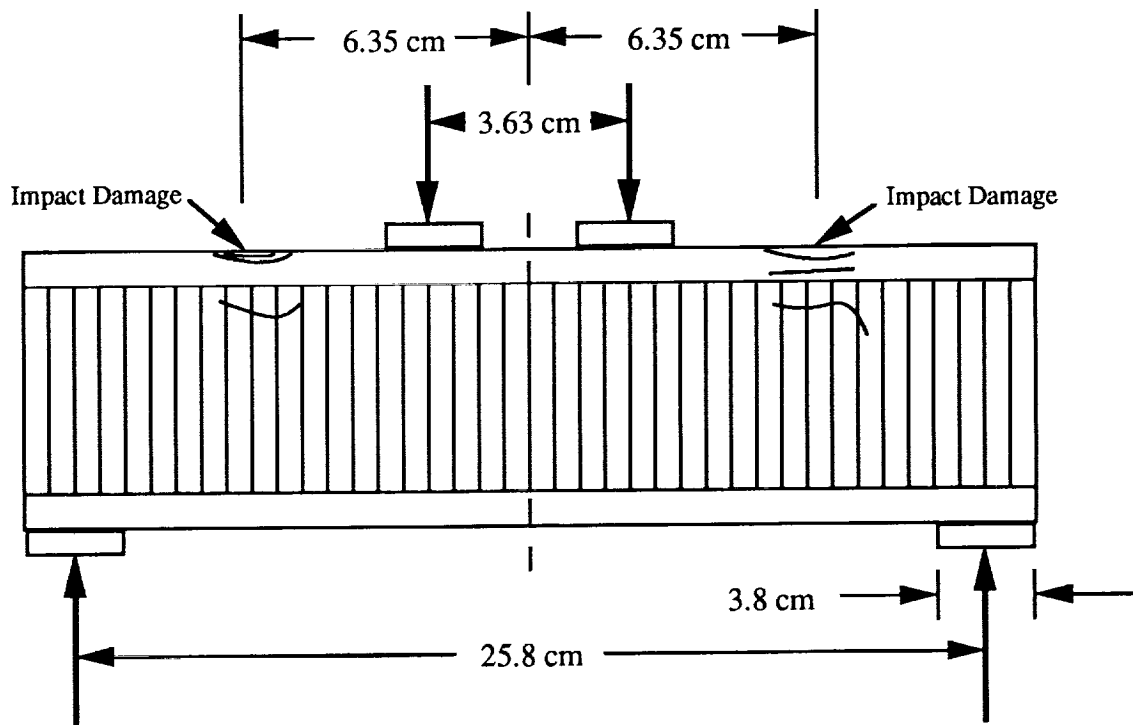


Figure 3. Dimensions of four-point bend tests.

3. Double Lap Shear Testing

Lap shear testing of honeycomb composites is normally done using ASTM standard C273. However, due to the thickness of the honeycomb, the specimens could not be made to the proper length. Because the shear strength after impact was needed, the original thin facings were used during the testing. The combination of the thin facings and thick core caused a peeling between the facings and core during the testing (fig. 1).

A new technique was thus devised to test the residual shear strength of the composite. This technique was termed the DLS test. After two specimens were impacted at the same energy levels on the eight-ply facing, they were bonded with the four-ply facesheets together (fig. 4). The sample was then placed in the test fixture of figure 5 and pulled in an Instron 1125. The strength obtained was divided by 2 to find the strength of the individual sample.

The specimen should be under shear stress completely, while C273 has a tensile or compressive component of stress involved. However, since two halves were actually bonded to make one DLS specimen and the weaker half of the DLS specimen fails, the average observed strength should be lower than the actual strength if tested using C273.

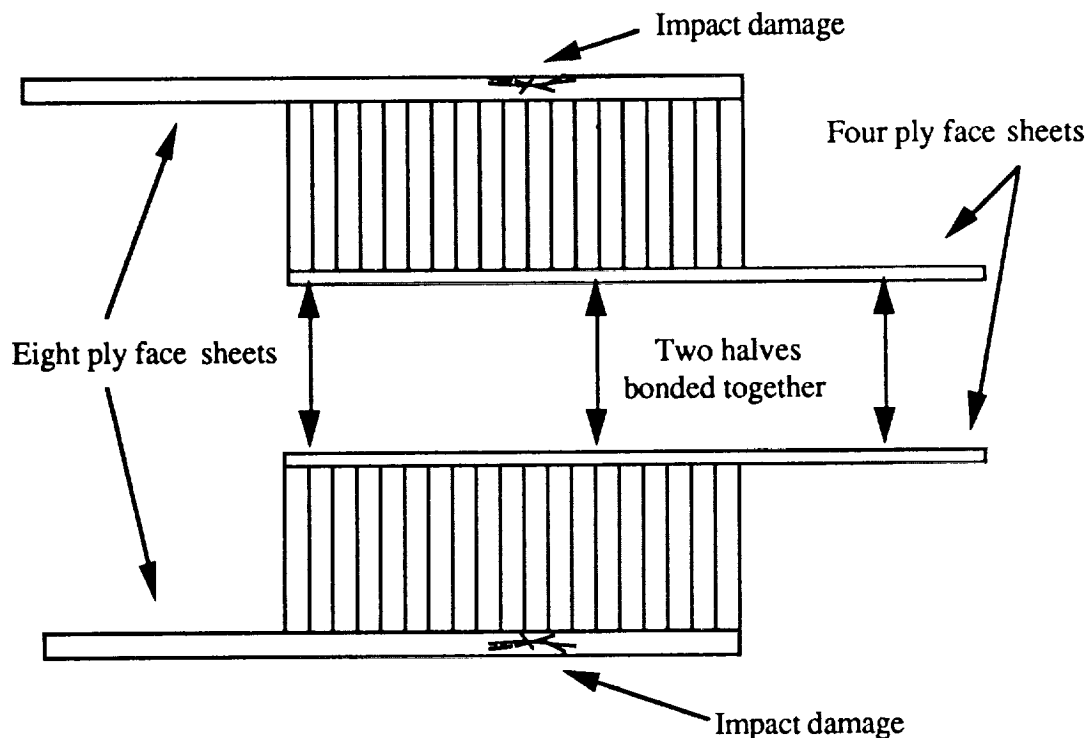


Figure 4. Method of bonding specimens for DLS tests.

"Double Lap Shear" Test Setup

All dimensions in inches.

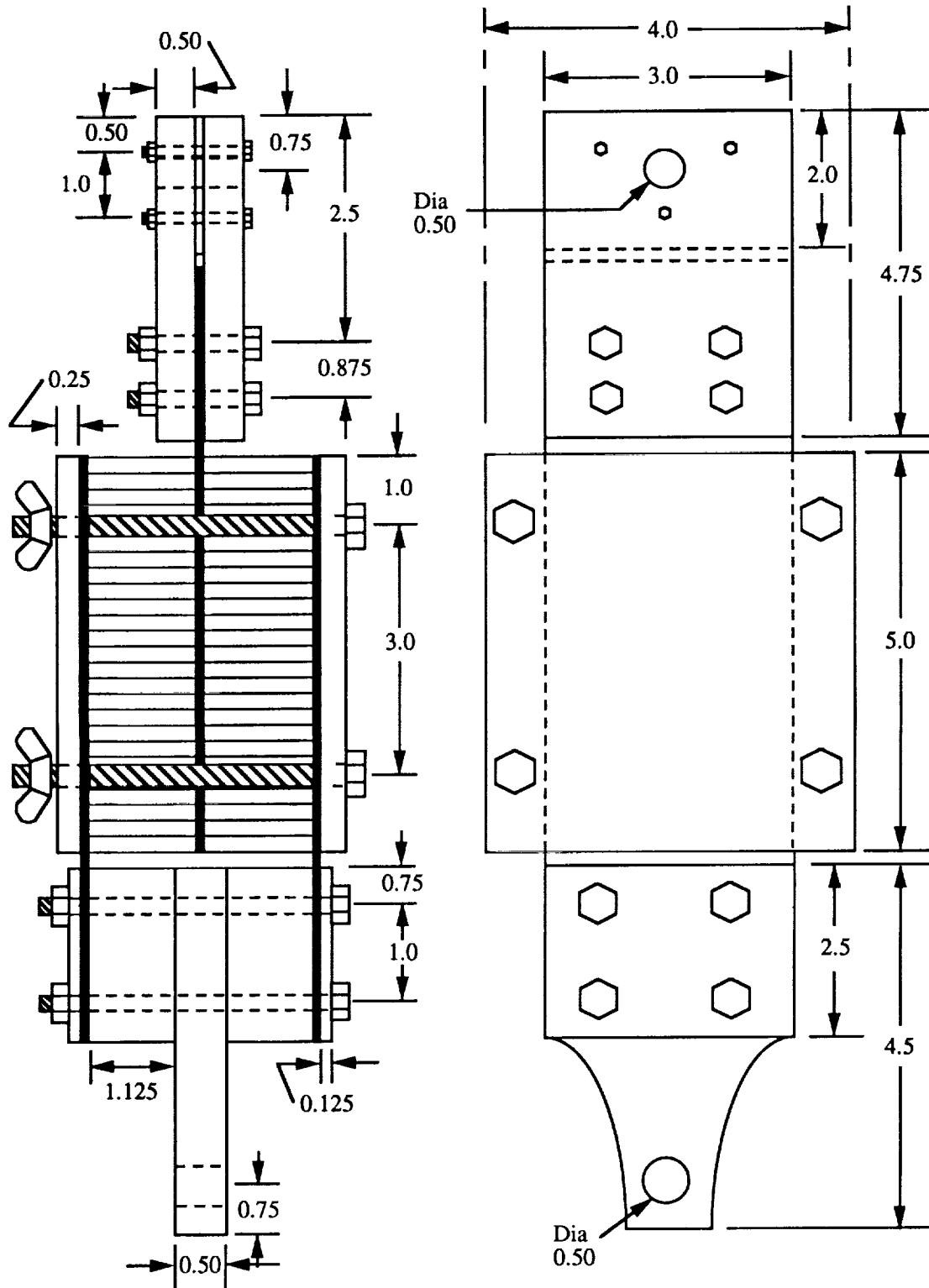


Figure 5. DLS test fixture.

IV. TEST RESULTS

1. Impact Testing

Damage of impacted specimens ranged from none visible to actual penetration of the facing. Small dents could be felt but not seen at energy levels as low as 0.66 J, while visible damage did not occur until 1.90 J in the samples with aluminum cores. Damage was first felt in samples with glass/phenolic cores at approximately the same impact energy levels, with visible damage first occurring at 1.95 J. At higher energy levels the aluminum received less damage than the glass/phenolic. At 5.2 J, for example, the glass/phenolic core samples had fiber breakage to the extent that a hole the diameter of the impacting tup was punctured into the facing with the brittle core crushed beneath. The aluminum core samples impacted at that energy level sustained less face sheet and core damage, with the core buckling rather than failing through brittle fracture.

2. Four-Point Bend Test

As expected, the specimens all failed due to core shear failure. The undamaged aluminum core samples failed at 810 kPa and steadily decreased in shear strength to 750 kPa at 8.6 J. The undamaged glass/phenolic specimen, however, failed at 700 kPa. A sharp decrease in strength was noticed in the range of 1 to 2 J of impact energy (fig. 6), with a drop in strength of over 100 kPa. The specimen with the greatest damage—5.2 J—failed at 530 kPa.

3. Double Lap Shear Test

Four undamaged DLS aluminum core specimens failed at an average value of 720 kPa. With increased impact damage, the strength steadily decreased as exhibited in the four-point bend tests. The strength decreased to 590 kPa at 4.2 J. Three undamaged glass/phenolic specimens were tested and failed at an average value of 640 kPa, and again a sharp decrease in strength was observed at an impact energy of about 1 to 2 J. The composites's strength gradually decreased to 450 kPa at 5.4 J.

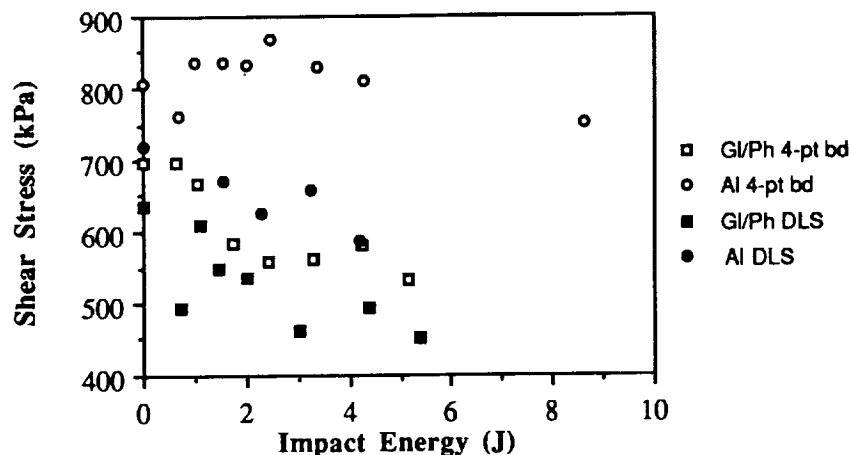


Figure 6. Shear stress versus impact energy.

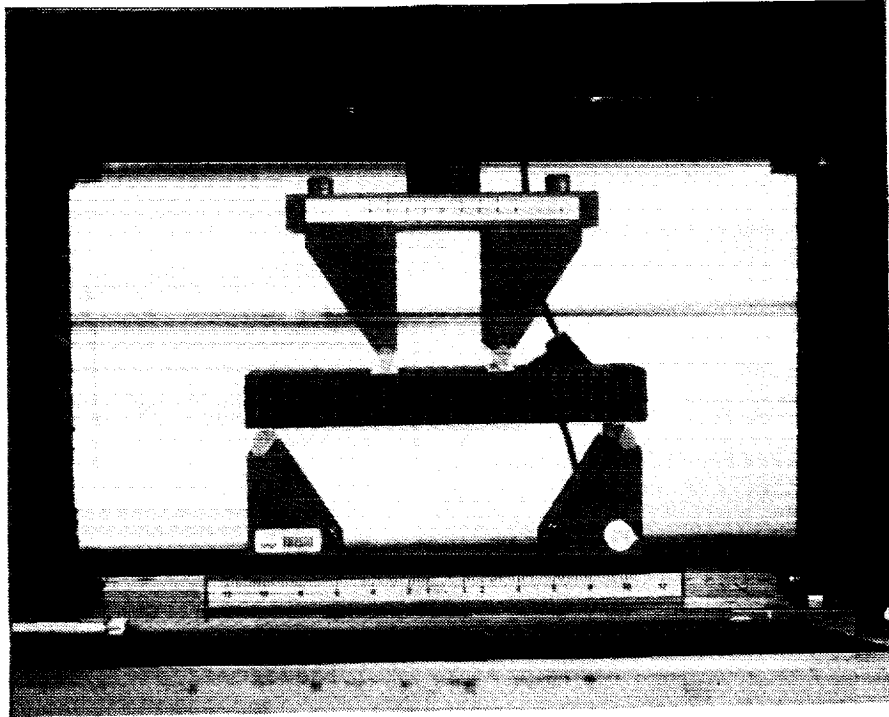
V. CONCLUSIONS

Although much scatter existed in the data obtained for the shear strength tests, a general trend was observed. The honeycomb composites with aluminum cores tended to gradually decrease in strength as the impact energy increased. The composites with glass/phenolic cores, on the other hand, tended to have a rapid decrease in strength between 1 and 2 J of impact energy. With higher impact energies, the glass/phenolic core specimens continued to gradually decrease in strength.

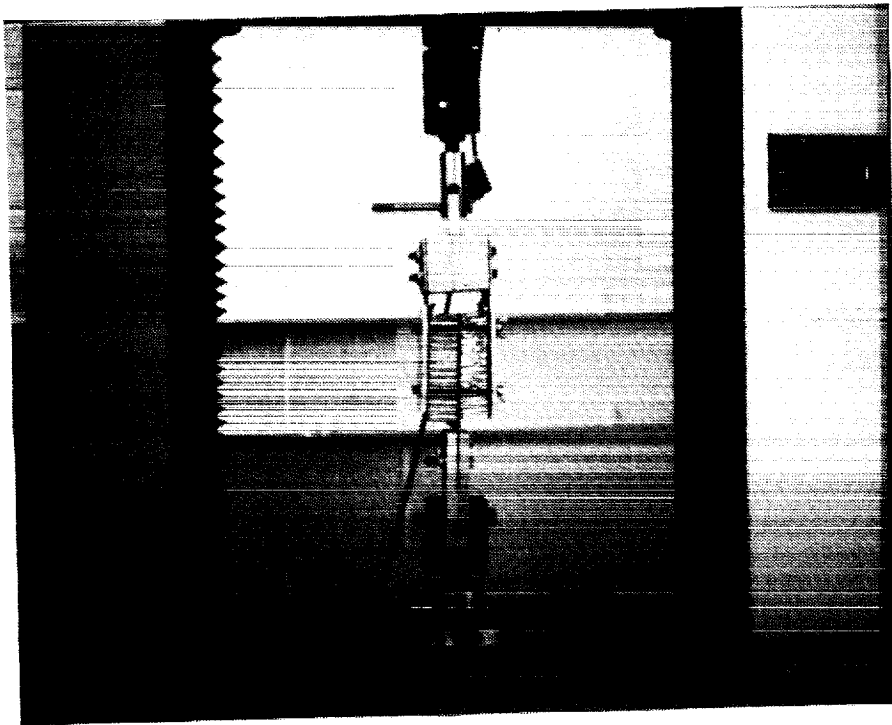
The DLS tests gave lower values in shear stress than the four-point bend tests. The lower shear stress in the DLS tests is probably due to the fact that two samples are bonded together and the weaker of the two fails. The DLS specimens also have less strength added by shear stress in the face sheets than the four-point bend specimens. The curves for impact energy versus shear stress, however, followed the same general trend for both tests. Thus, the modes of failure were similar, and the tests are comparable.

APPENDIX

PHOTOGRAPHS OF TESTING TECHNIQUES USED



Four-Point Bend Test



DLS Test

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

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| 16. Abstract Sandwich composites of aluminum and glass/phenolic honeycomb core were tested for shear strength before and after impact damage. The assessment of shear strength was performed in two ways; by four-point bend testing of sandwich beams and by a novel "double lap shear" (DLS) test. This novel testing technique was developed so smaller specimens could be used thus making the use of common laboratory scale fabrication and testing possible. The two techniques yielded similar data. The DLS test gave slightly lower shear strength values of the two methods but were closer to the supplier's values for shear strength. | | | | | |
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